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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

CONTROL OF THE CITRUS THRIPS IN CALIFORNIA AND ARIZONA.

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INTRODUCTION.

The citrus thrips,[1] a minute orange-yellow insect, has in the past few years caused extensive damage to citrus fruits in the San Joaquin Valley of California and also occasioned considerable injury in southern California and Arizona orange groves.

The nature and extent of the injury caused by this insect and its life history and habits were carefully studied, and extensive experiments for its control were conducted by the writer during the period from 1910 to 1912. It is the purpose of the present paper to give briefly the practical control measures resulting from these studies.

INJURY.

The citrus thrips is a sucking insect feeding on the plant juices of the leaves, the fruit rind, and the bark of tender stems, in much the same manner as the mosquito draws its food from its victims. For this reason the insect can not be killed by stomach poisons sprayed on the plant, but must be controlled by sprays that kill by contact.

The injury caused by the citrus thrips begins with the seedling orange tree. The leaves are scarred and distorted, and to a certain extent the stock is devitalized. When the seed stock is budded and the foliage of the seedling trimmed off, the thrips attacks the bud. Nursery buds will make a fine, luxuriant growth of 2 or 3 feet in a

[1] (*Euthrips*) *Scirtothrips citri* Moulton; order Thysanoptera, family Thripidæ.

NOTE.—This bulletin is of interest to the citrus growers of the Pacific coast and the Southwest.

season if properly sprayed to protect them from thrips. On the other hand, many nursery trees have the leaves and stems so badly scarred and twisted as to give them a blighted, unsightly appearance, and are so retarded in growth that they must be held in the nursery for a year or more beyond the proper time for sale in order to meet the size requirements, thus decreasing the nurseryman's profit by the cost of the extra care. It sometimes happens that this class of stock is sold along with better trees, and the thrips injury continues for

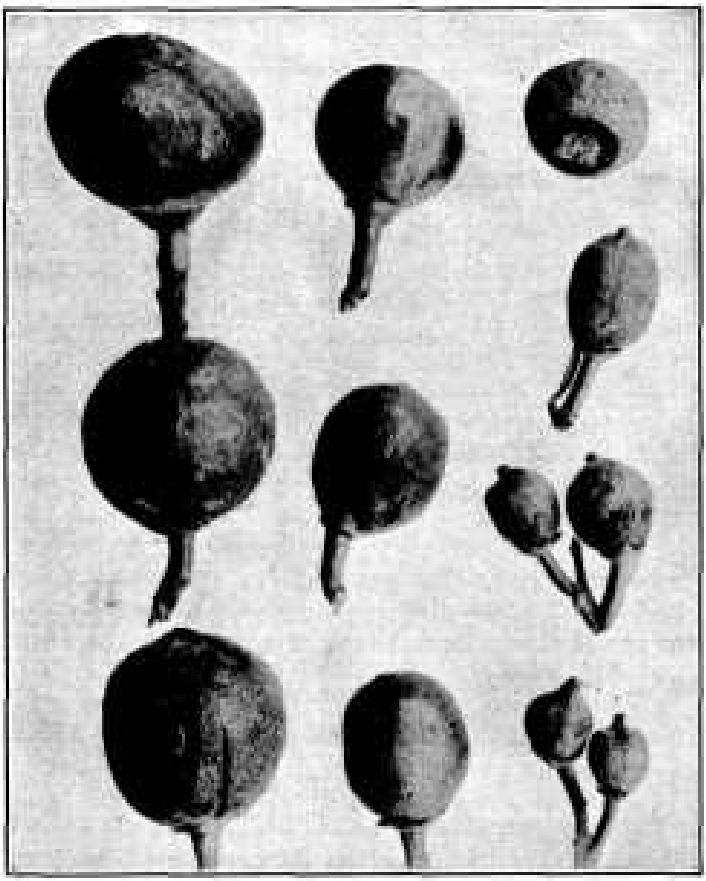

FIG. 1.—Injury to young oranges by the citrus thrips (*Scirtothrips citri*). (Original.)

several years in the orchard. The writer knows of 5-year-old and 7-year-old groves in the foothills of Tulare County which have been held back, principally by thrips, to such an extent that the trees are no larger than 3 and 5 year trees in less infested situations. From the general appearance of such trees it seems evident that they will never attain the size and bearing capacity of trees which have escaped severe thrips infestation in the nursery and during their early years in the orchard.

As the young fruit appears it in turn is attacked (fig. 1), and its market value at maturity is much reduced by the enlarged feeding scars and scabbing (fig. 2). A larger percentage of small-sized fruits than ordinarily develop results, and there is a total loss, as the result of early and severe scabbing, of a proportion of the fruit. To calculate the damage caused by the insect in reducing the grade of the fruit, it is necessary to know the system of grading and the relative market value of the grades. Three packs are usually made in California packing houses at the time of this writing, these packs or grades being variously designated as "Fancy," "Choice," and "Standard"; "Extra Fancy,"

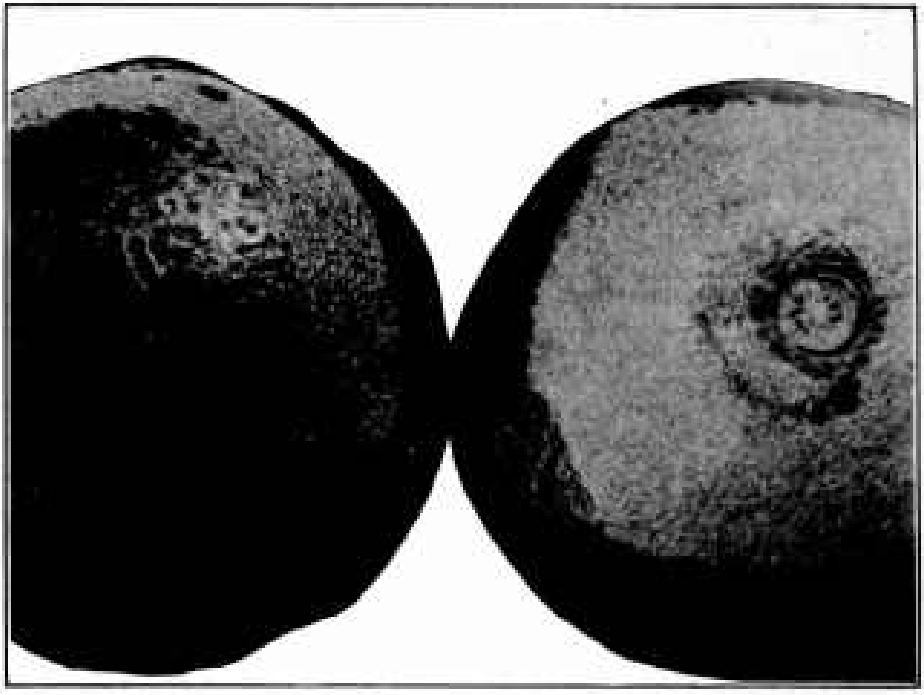

FIG. 2.—Mature oranges, showing injury by citrus thrips. (Original.)

"Fancy," and "Choice"; or "Extra Choice," "Choice," and "Standard." Whatever the terms used there is usually little difference in the quality of fruit of corresponding grades at the different packing houses. In other cases only two divisions are made, the first grade generally being designated as "Orchard Run" and the second or lower grade as "Standard." Under the latter system the quality of the fruit composing the first grade is about the same as would be obtained by placing together all the fruit of the first and second grades of the three-grade pack. Statistics upon the quantity of fruit shipped from the entire San Joaquin Valley and the prices received for it are not available, but from Lindsay and its tributaries 1,525 carloads of navel

oranges were shipped in 1911. The approximate average number of boxes of fruit to the car is 390, making 594,750 boxes for the season's shipment. From examination of thousands of oranges in the field, throughout the district and in many groves, it was calculated that 34 per cent of all the fruit would be classed as first grade so far as thrips injury was concerned, 43 per cent as second grade, and 23 per cent as third grade. Returns received by different packing houses on a total of 358,000 boxes of navels of all grades for the season indicated the following average differences in price per box between the different grades. First-grade fruit averaged 37 cents more per box than that of second grade; the latter 28 cents more than that of third. Fruit shipped in only two grades gave an average difference of 51 cents per box in favor of the first grade. It may be seen from the foregoing data that 43 per cent, or 255,742 boxes, of the Lindsay fruit was reduced to second grade at a loss of 37 cents per box, or $94,624.54; 23 per cent was reduced to third grade at a loss of 65 cents per box, or an additional $88,914.80. There was thus a total loss for the Lindsay district alone of approximately $183,539.34 in the season of 1911 from grade reduction caused by thrips.

SUMMARY OF SEASONAL HISTORY.

In seasons such as 1911, adult citrus thrips first appear in April and increase rapidly during April and May, during which time the insects are congregated largely on the fruit and foliage of the orange. During part of June, July, and August the adults leave the toughening fruit and leaves of the orange and disperse over miscellaneous food plants, and it is during this period of wider separation that mating and oviposition are somewhat checked. In August and September there is a series of flights back to the late summer growths of the orange, where the insects concentrate in large numbers, mating and actively depositing the eggs which produce the insects of the following spring.

The citrus thrips begins to disappear about the middle of October, and after December practically none can be found. There are generally a few larvæ and adults in places on the trees until the early part of January, at which time they disappear completely. The eggs which are deposited in the stems and leaves of the orange in the fall mostly pass the winter successfully, hatching during the ensuing March, April, and May. The seasonal activities of the citrus thrips, as related to orange blossoming, growth periods, and spraying are summarized graphically in figure 3.

SUMMARY OF LIFE HISTORY.

There is a tendency on the part of the citrus thrips to breed throughout the year. All stages of the insect are found on the trees throughout November and December. Larvæ, pupæ, and adults gradually

die off as the weather grows colder, until by the middle of January all have disappeared. The winter is passed only in the egg stage. Eggs deposited in the leaves and stems, mostly during late August, September, and October, hatch and the larvæ appear in March, April, and May.

The average duration of the egg stage of summer generations varies from 10 to 18.8 days during May and June, 6.8 to 8.5 days in July and August, and 17 to 18.8 days in September and October.

The average larval stage varies from 6.6 to 13.7 days during April and May, 4.2 to 9 days from June to August, and 6.7 to 11.2 days in September and October.

The average pupal stage varies from 4.7 to 13 days during April and May, 2.8 to 5.1 days from June to August, and 5 to 19.9 days from September to November.

Pupation takes place in crevices on the tree trunk, in dead leaves and rubbish under the trees, and under clods and particles of trash

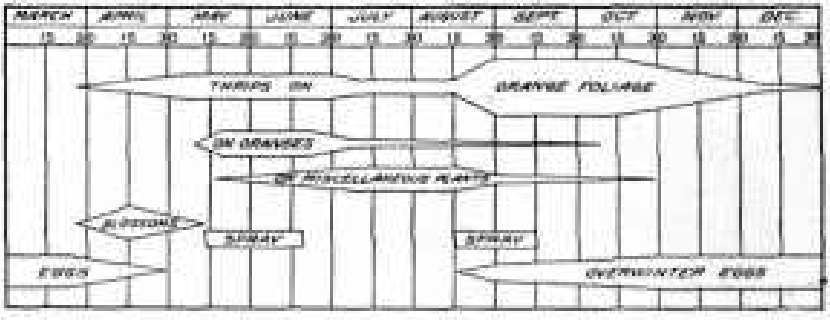

FIG. 3.—Graphic illustration of the seasonal activities of the citrus thrips as related to blossoming and later growth periods of the orange, and indicating also the spray periods. (Original.)

on the ground, but never in the ground. The pupa is naked, does not construct a cell, and is at all times capable of locomotion.

The average duration of adult life is from 25 to 35 days, with extreme instances running to from 46 to 49 days. Adults can live from 2 to 6 days only without food.

The number of generations in a season will depend upon the character of the season. An early, warm spring followed by a prolonged, hot summer may result in the production of eight or more generations. In seasons such as 1911, six full generations may be expected between the middle of April and the first of November. For purposes of control the citrus thrips must be treated as an insect having only a single generation a season, and with an egg-laying period extending from April to November.

REMEDIES FOR THE CITRUS THRIPS.

Certain measures against the citrus thrips have been persistently recommended in spite of abundant evidence of their inapplicability. These are usually directed against the pupal stage and consist in the application of insecticides to the soil, breaking the soil up fine to destroy the insects supposedly pupating there, and burning dead leaves and trash, which accumulate under the trees, to destroy the pupæ. These methods are worthless for the reason that the thrips

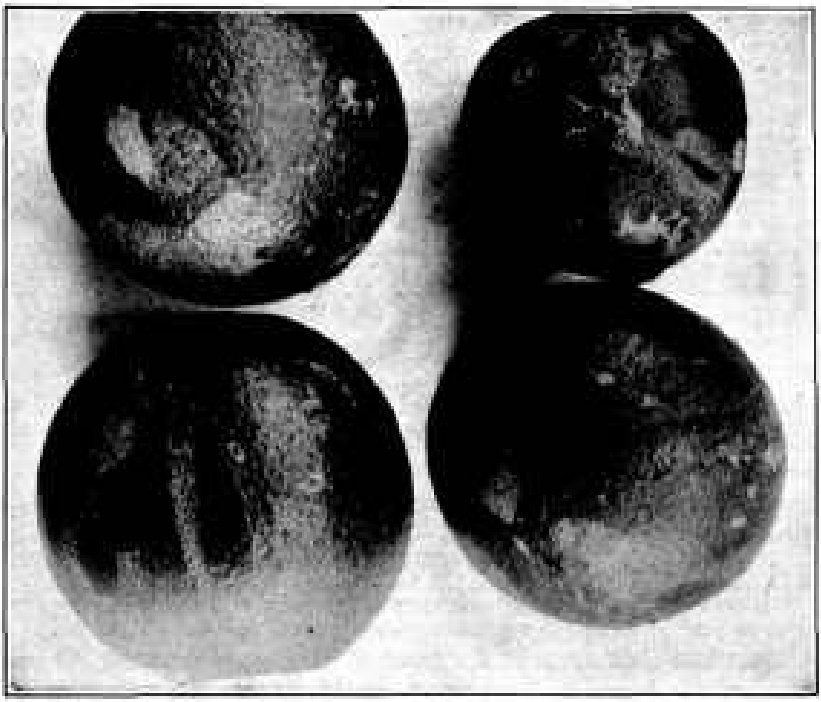

FIG. 4.—Resin-wash injury to half-grown oranges sprayed for the citrus thrips. (Original.)

do not go into the soil at all, and only a varying and often small percentage of them pupate in the trash. Fumigation with hydrocyanic-acid gas will reach and kill only the larvæ and a small number of adults, and is accordingly too expensive to use. Distillate-oil emulsions and proprietary emulsions containing distillate, even when used as weak as 2 per cent, stain the ripe oranges, and are otherwise so injurious that it is considered unsafe to use them. Commercial lime-sulphur is not noticeably injurious when used at less than 1 part to 28 parts of water. Resin wash can not be safely used on orange trees at any strength. Where the resin mixture comes into contact with the fruit the epidermal cells are killed and

a shallow brown scab is formed. (Fig. 4.) Where the liquid collects in large drops it forms a thick, amber-to-black scab which does not slough off readily. About 20 per cent of the fruit at picking time was thrown into the lowest grade owing to scabbing through the use of the weakest resin wash.

There is only one cheap and effective method of citrus-thrips control, viz, the application at high pressure of contact insecticides, preferably mixtures containing sulphur in solution. Sulphur mixtures at the proper strength have given uniformly high killing results and have thus left no doubt as to their insecticidal power over this species. They further show a more or less marked tendency to repel the insects and prevent rapid reinfestation of sprayed trees.

SPRAY MIXTURES AND DILUTIONS.

Of the large number of combinations of insecticides tested, the following have given the best results, and any of the mixtures here recommended may be relied upon to do good work:

1. Commercial lime-sulphur.—If the lime-sulphur is of a density of 36 degrees on the Baumé scale, dilute 1 gallon with 56 gallons of water; if of a density of 33 degrees Baumé, dilute 1 gallon with 50 gallons of water.

2. Sulphur-soda solution.—Two gallons of the stock solution, prepared as described on page 8, diluted with 25 gallons of water.

3. Commercial lime-sulphur and blackleaf tobacco extract (40 per cent nicotine sulphate).—Dilute 1 part of the commercial lime-sulphur, if 34 to 36 degrees Baumé, with 86 parts of water; if 30 to 33 degrees Baumé, with 75 parts of water. Then add 1 part of the tobacco extract to 1,000 parts of the lime-sulphur diluted as above.

4. Blackleaf tobacco extract (40 per cent nicotine sulphate).—Dilute 1 part with 800 parts of water.

COMMERCIAL LIME-SULPHUR.

The commercial lime-sulphur, diluted with water and without the addition of other chemicals, is preferred to any of the other insecticides because of its cheapness and convenience in mixing. Very good grades of lime-sulphur can be purchased in the market at a reasonable price, and since the preparation of this product requires care and experience, and as it must be made fresh each time or special precautions taken to store it in air-tight containers, its home manufacture is not advised. When necessary to carry the market product over a season it is essential to protect it absolutely from the air, as it rapidly loses its insecticidal power when exposed through leaky barrels or an open bung.

SULPHUR-SODA SOLUTION.

Another mixture containing sulphur as the most important ingredient is made by dissolving sulphur with the aid of caustic soda, according to the directions given below. This mixture, though

practically as effective in controlling the citrus thrips as lime-sulphur, can not be purchased ready-made and is therefore less convenient to handle. Furthermore, at the present writing it costs just as much per dilute gallon as the factory-made lime-sulphur.

The sulphur-soda stock solution is prepared as follows:

Powdered sulphur	30 pounds.
Powdered caustic soda (98 per cent)	15 pounds.
Water to make	30 gallons.

The sulphur is made into a paste with water, and while the mixture is being constantly stirred the soda is added in sufficient quantity to start boiling. As boiling becomes violent a little water is added to retard it. When the sulphur has all been taken into solution enough water should be added to bring the stock solution up to 30 gallons. If made according to the foregoing directions the final product will be a clear, amber-colored liquid much resembling good commercial lime-sulphur.

PLAIN TOBACCO EXTRACTS.

Tests with plain tobacco extracts without the addition of lime-sulphur or other preparations have given very good results when the tobacco has been used at sufficient strength. Tobacco extract containing 40 per cent nicotine used at the rate of 1 part to 800 parts, liquid measure, of water is quite satisfactory; when diluted at the rate of 1 part to 1,600 parts water, however, its efficiency is noticeably lowered. It can not be recommended for this work in solution weaker than 1 to 1,000, and should preferably be used at the rate of 1 to 800. The commercial tobacco extract containing a high percentage of nicotine sulphate is very convenient to handle and costs approximately $0.016 for each gallon of the diluted spray, when used at the rate of 1 part to 800 parts of water.

TIME AND NUMBER OF SPRAY APPLICATIONS.

Unfortunately no specific dates, which will hold for every season, can be fixed for the applications of the spray. The investigations of the seasons of 1910 and 1911 have shown that the date on which the thrips first become numerous and injurious and the navel-orange blossoms lose their petals varies as much as 30 days in certain seasons, due to the nature of the spring weather, and, further, that it varies in different orchards in the same season. The greatest injury to the fruit is done between the time the petals fall and the fruit is half grown. It has been demonstrated that three applications of the insecticide are necessary during this period to prevent marking of the fruit. The first spring growth has usually hardened by the time

the petals have all fallen, and the thrips then seek the young fruit. The petals do not all fall at once, but come down gradually, and the transfer of thrips is therefore gradual.

The first application should be made as soon as four-fifths or more of the petals have fallen. This checks the insect at a time when the orange is most susceptible of deep injury and when the blossoms have passed the period at which pollination might be interfered with by the spray.

After the first application more larvæ will issue from eggs deposited in the very young fruit, and additional adults will appear from the specimens pupating at the time of the application. The second application must therefore be timed to prevent this renewed attack, which may be expected to reach the danger point in from 10 to 14 days after the first spraying. This second spraying should not be too long delayed, as a comparatively few larvæ may, by their persistent habit of feeding in a circle about the base of the fruit, cause considerable injury. Special effort should be made to drench all the fruit as well as the few remaining tender leaves thoroughly, as it is here only that the insects occur.

The third application may be longer delayed if the first two have been thorough and well timed. It generally takes the insects from two to three or four weeks to become dangerously numerous again, as they reinfest the sprayed trees very much more slowly after the second application.

After the third application the fruit rapidly loses its attractiveness, and the insects then find it necessary, in order to secure food, to spread out over the few remaining tender orange leaves and certain miscellaneous food plants. During the latter part of August and in early September there is usually another abundant growth of shoots upon which the thrips congregate in great numbers. A fourth application in late August or more probably in September should be timed to catch the insects as soon as they become numerous and before any great amount of leaf injury appears.

The importance of protecting this growth is evident to those familiar with the stunted condition of orange trees in certain orchards of Tulare County as the result of continuous feeding of large numbers of thrips during the first five or six years of growth. The writer has in mind an orchard in which trees five years from the nursery are no larger than the average 2-year-old trees in localities more favorably situated with regard to thrips, and which each year have a very large percentage of the leaves so severely injured that they roll up into tight curls.

SPRAY APPLICATIONS TO NURSERY STOCK.

While definite dates can not be given for the application of sprays to nursery stock, it follows in the case of trees budded in the fall, where the original stock is allowed to put forth a good growth in the spring, that it is sometimes advisable to spray during April, but only when thrips have become quite numerous and for the purpose of ridding the trees of them before the scion has grown sufficiently to attract them. Preferably the stock should be largely cut back as soon as the bud is well under way, and this is generally done in Tulare County before May 1. The prunings should be burned in every case to destroy eggs and larvæ which may be present. The growing scions must then be watched carefully, and as soon as thrips appear in numbers spraying should begin. They should be further watched with the same care throughout the remainder of the growing season and sprayed as often as the abundance of thrips makes them liable to severe injury. Nursery stock will usually require from three to five applications a season, depending largely on the amount of growth it produces. Once the scion has completed its first growth and become distasteful to thrips the next most important growth will usually occur late in July or in August.

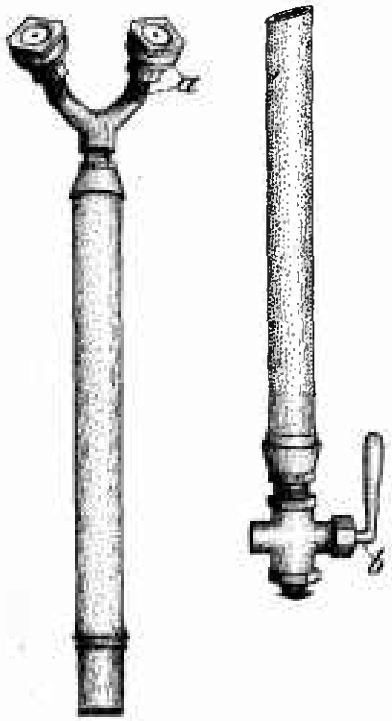

FIG. 5.—Correct spray rod and nozzle connections: *a*, Two nozzles fitted on "Y" branch; *b*, shut-off at base of spray rod. (Original.)

To summarize, the first application should be made when thrips begin to get numerous on the spring growth, usually between April 15 and May 15, after which from two to four further applications will be necessary, according to the conditions of infestation.

SUGGESTIONS ABOUT SPRAYING.

The gasoline-power outfit, by reason of its large nozzle capacity, simplicity, reliability, and comparatively low cost of operation, is the only class of sprayer here recommended for spraying bearing orchards, young orchards in excess of 10 acres, and large nurseries. Hand-power outfits, when of the right type and capable of maintaining a pressure of not less than 125 pounds, are suitable and even preferable

for spraying seed-bed and nursery stock, and they may also be used in young orchards of small acreage.

The spraying outfit should be on hand, set up, and in perfect running condition not later than April 1, and the insecticide materials at hand and conveniently located near the water supply, and as close as possible to the orchard or nursery to be sprayed. It is necessary to order supplies not later than the January or February preceding the spraying operations in order to insure having the material at hand when wanted.

HOW TO SPRAY BEARING ORCHARDS.

It is best to use only two 50-foot leads of hose on a power outfit, with 10-foot rods each fitted with a "Y" (fig. 5) which is angled to handle two nozzles. The latter should be of the large chamber type, with disks bored to one-sixteenth inch, and should throw a double cone of spray which breaks into a fine mist at about 4 feet (fig. 6). The first application should usually be started just before all the petals are down. While the sprayer is being driven between the rows each rodman should begin work at about the middle of his tree on the side away from the sprayer and work around the tree until he meets the starting point; he should then switch to the same point on the next tree without shutting off the nozzles and with as much economy of movement as possible. (See figure 7, which shows easy and correct position for spraying.)

FIG. 6.—Mist spray from twin nozzles. (Original.)

The nozzles should be held about 2 feet from the tree so that the broad portion of the stream plays upon fruit and leaves. The trees should be swept from tip to base, special attention being given to the fruit and the tender growth, where the insects congregate. The pressure, if maintained at 150 pounds or more, will turn the leaves over so that both sides will be sprayed. No

attention need be paid to the inner portions of the tree, as thrips do not occur there.

One should not attempt to spray too many trees with a single outfit, and an application once commenced should be finished within 10 days. It has been found after much experience that only about 25 acres of from 12 to 18 year old trees or 50 acres of from 5 to 7 year old trees can be successfully handled with one gasoline-power sprayer. This is calculated on the basis of ten 200-gallon tanks of spray per day, allowing 8 gallons per tree for trees from 12 to 18 years old or 4 gallons for trees from 5 to 7 years old, allowing 100 trees to the acre. It is a common mistake to use the wash too sparingly and to try to get over the ground too fast. Table I, published also in a former report,[1] was prepared to show approximately the correct amounts to apply to trees of different ages, and from it the quantity of spray material required for the season may be estimated.

FIG. 7.—Correct position of operator in spraying. (Original.)

TABLE I.—*Quantities of liquid required in spraying for the citrus thrips.*

Age of trees.	One application.	
Years.	Gallons dilute spray per tree.	Gallons per acre of 100 trees.
2 to 3...	2	200
5 to 7...	4	400
8 to 10..	5	500
12 to 18.	8	800

[1] Jones, P. R., and Horton, J. R. The Orange Thrips: A Report of Progress for the Years 1909 and 1910. U. S. Dept. Agr., Bur. Ent., Bul. 99, pt. 1, iv+16 p., 2 fig., 3 pl., Mar. 6, 1911. See p. 15.

The spraying must be very thorough, and to be effective the insects must actually be hit by the spray. It will very much improve the results if the rodmen are shown the insect they are to spray for and just where it will be found in greatest numbers. In this way the object of spraying is made definite. By keeping the thrips reduced to a minimum during the period between the dropping of the petals and the time when the fruit is half grown, most of the fruit scarring and the leaf curl of the early summer growths of foliage can be prevented. An application at the proper time in late August or in September will prevent the severe leaf curling which usually occurs to all late summer growths.

HOW TO SPRAY NURSERIES AND YOUNG TREES.

For large nurseries, where the gas-engine outfit can be advantageously used, it is preferable to the hand outfit. Two 25-foot or even 15-foot leads of hose and 12-foot spray rods are generally most convenient for this work. However, when an outfit has already been fitted with 50-foot hose and 10-foot rods, with the intention of spraying older trees as well as nursery stock, this equipment may be made to serve very well for the latter. In such case the excess hose length should be coiled over a peg or bracket fastened to the spray tank or engine hood, so that the young trees will not be injured by the dragging hose. It is preferable in setting out a nursery to leave driveways wide enough to accommodate a sprayer and team at intervals throughout the length of the bed. Where it is desired to have the nursery rows 4 feet apart, which is the usual practice, it is convenient to have wagon room between the fourth and fifth rows from one side, and again between the 12th and 13th, 20th and 21st, etc. With this arrangement eight rows of trees, four either side of the driveway, may be reached each trip, using 12-foot spray rods; eight more rows may be taken on the return trip, etc.

The large chamber-type or single Bordeaux nozzles may be used to good advantage, but the rapidity of delivery of the spray need not be so great as that necessary for orchard work. It is better to progress more slowly, covering all portions of the little trees, without undue waste of liquid. The trees will need attention only when the growth is tender.

COST OF SPRAYING AS COMPARED WITH RETURNS.[1]

Thrips injury to citrus fruits is confined to the rind and does not appreciably affect the eating quality of the fruit. Except in seasons of unusually gross infestation no great amount of fruit is lost entirely by reason of thrips injury. The argument has been advanced that where the fruit is separated into but two commercial grades, which embrace everything fit to ship, as is now largely the case, thrips injury will have but little effect on the price. The damage thrips do to the trees by interfering with the functions of the leaves throughout the early years of growth, however, is generally overlooked. The following statement takes no account of this indirect injury to the trees, which is difficult to estimate, but merely gives the profit realized from producing a better grade of fruit by spraying.

Cost of spraying one acre of 18-year-old navel orange trees.

Labor:	
2 rodmen at $2.50 each per day, cost per acre	$1.22
Driver and team at $5 per day, cost per acre	1.23
Cost of labor per acre, one application	2.45
Insecticide:	
14 gallons lime-sulphur at 14 cents, cost per acre, one application	1.96
Fuel, oil, and miscellaneous:	
Gasoline, 1½ gallons at 25 cents, per acre, 3 applications	.625
Oil at $1 per gallon, per acre, 3 applications	.025
Repairs and batteries, per acre, 3 applications	.21
Estimated cost of fuel, oil, etc., per acre, 3 applications	.86
Cost of labor per acre, 3 applications	7.35
Cost of insecticide per acre, 3 applications	5.88
Cost of fuel and miscellaneous per acre, 3 applications	.86
Total cost of treating 1 acre of 18-year-old navel orange trees	14.09

Returns from sale of fruit.

Number of packed boxes fruit produced per acre	324
Per cent of fruit raised from second grade to first grade by spraying	18
Boxes raised from second grade to first grade by spraying	58
Difference in price received per box for first-grade over second-grade fruit	$0.51
Amount saved per acre by spraying	$29.58

Profit from sale of fruit.

Amount saved per acre by spraying	$29.58
Cost of spraying per acre	14.09
Clear gain per acre from the treatment	15.49

[1] The figures given upon cost of spraying are based on the Bureau of Entomology's own spraying work in the season of 1911. The number of boxes of fruit given, 324 per acre, was the actual production of the portion of grove under experiment, and as these trees were not at their best and since 18-year-old trees usually produce more than 324 boxes per acre, the saving effected by spraying would tend to be greater in most cases. The difference of $0.51 per box between first and second grade fruit was that which was actually shown by packing-house returns, and practically all the grade reduction was caused by thrips alone.

In the above calculation the cost of spraying an acre of 18-year-old trees is higher than will usually be the case, since, as a rule, the grower is obliged to have a team on hand all the time and may therefore reduce the item of team hire; he may also be able to reduce the cost of labor somewhat in many cases. In seasons of gross infestation, and in certain orchards every season, the returns will be greatly increased over the figures given because of the excessive infestation in such seasons and orchards.

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